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GB A 2025628 GB 1140180 WO A1 8100774
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(54) System for multichannel processing of redundant wellbore sensor

(57) In order to provide enhanced reliability in the measurement of downhole parameters within a borehole, each downhole parameter is sensed by a pair of detectors 131, 132 and a stream of datapoints representative thereof is generated. Each stream of datapoints is analysed by a processing system 135 relative to the expected statistical norms and physical parameters known to be associated with the characteristics of the detectors 131, 132, to determine whether the datapoints are within the acceptable ranges and parameters. A flag is generated for each stream of datapoints found to be outside the ranges and parameters. The flags are recorded by a recorder 137 together with the streams of datapoints found to be within the acceptable ranges and parameters.

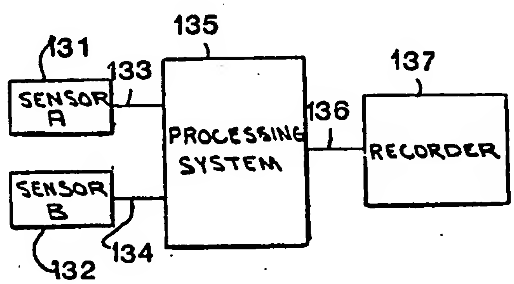

FIG. 2

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The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.
This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1982.

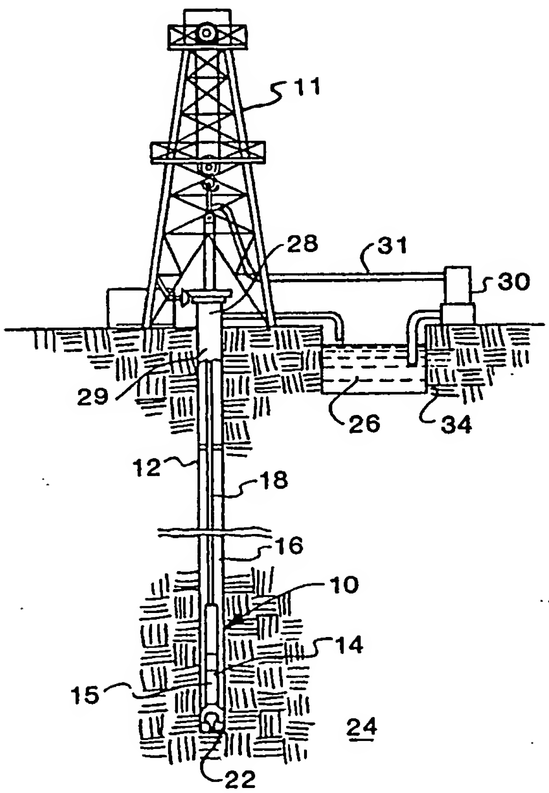

FIG. 1

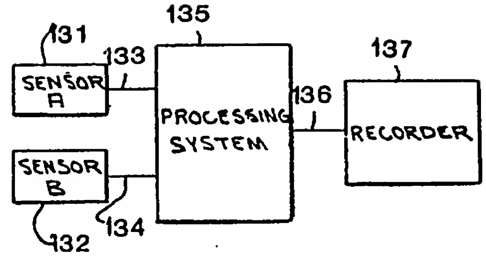

FIG. 2

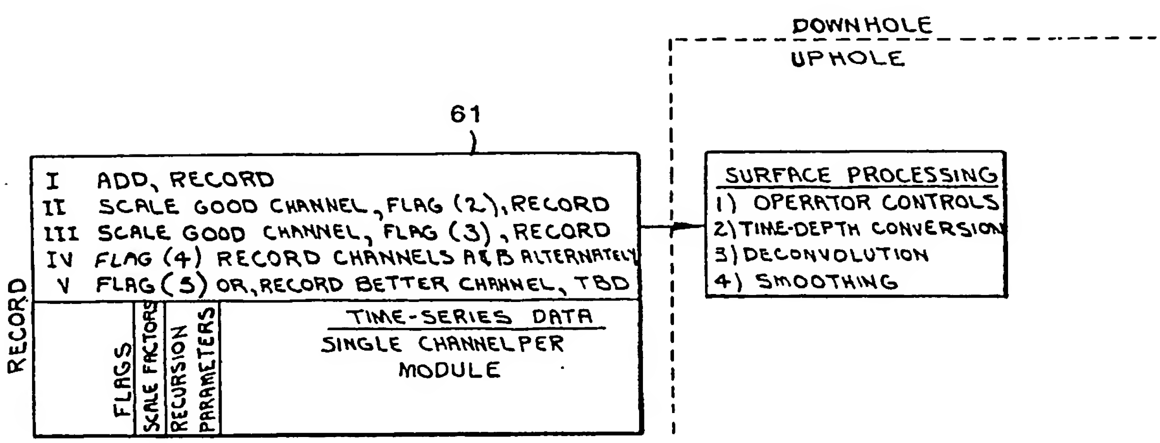

FIG. 4

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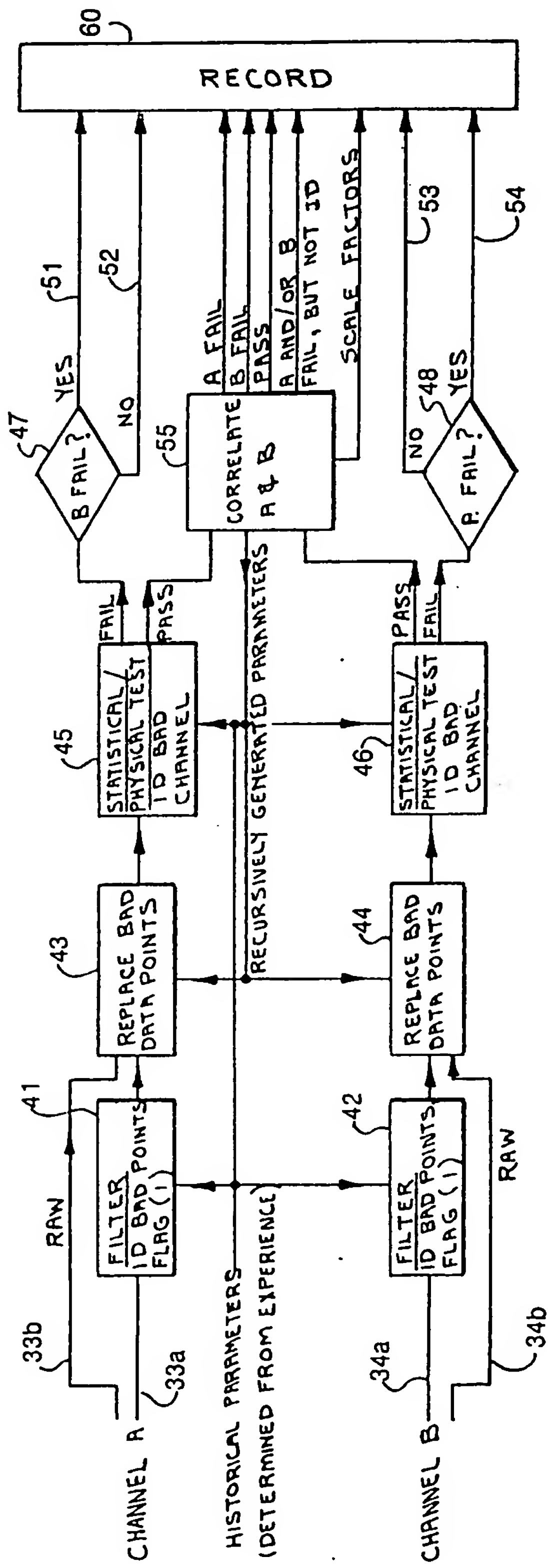

FIG. 3

SPECIFICATION

System for multichannel processing of redundant wellbore sensor

The invention relates to the use of redundant sensors for measuring wellbore data while drilling, and more particularly, to the processing of data obtained from redundant wellbore sensors to increase the reliability of measured parameters.

In the drilling and production of petroleum products from earth formations, the logging of a borehole and the accuracy with which the borehole is logged is critical to determine the presence and location of petroleum products within the formations along the borehole. Well logging has generally been accomplished in the past by lowering a measuring instrument attached to a conductive cable into the open borehole and measuring various parameters associated with the characteristics of the formations as the instrument is moved along the borehole. Since logging tools frequently include several sensors for simultaneously measuring various parameters associated with the earth formations along the borehole, there is generally only one sensor for measuring each parameter.

In recent years technology has enabled the measurement of borehole parameters while the drilling operation is in progress. The capabilities of a measuring-while-drilling system have greatly enhanced the efficiency of the drilling operation by allowing the drilling operator to have direct real time information with respect to the direction and angle of the borehole, downhole pressures and temperatures and weight on bit measurements as well as various parameters directly associated with the characteristics of the earth formations through which the borehole is passing. Measuring-while-drilling technology has greatly enhanced the efficiency of the drilling operation by eliminating the need to stop the drilling operation and remove the drill string in order to make borehole measurements. In addition measuring-while-drilling technology has dramatically increased the safety of the drilling operation by providing real time indication of downhole conditions so that corrective steps can be taken immediately upon the occurrence of emergency conditions during the drilling operations.

In measuring-while-drilling it is also conventional to provide only one sensor for measuring each of the downhole parameters which are being monitored. For example, a single sensor would be used for the measurement of each of the parameters of natural gamma radiation, inclination of the borehole, azimuth of the borehole, drill bit speed and torque, weight-on-bit, drilling fluid pressure, temperature and resistivity and many other parameters producinq information useful to the drilling operator. The use of a single sensor for each of these parameters means that in the event a sensor malfunctions or fails completely, the drilling operator is either provided with erroneous data or no data with respect to that particular parameter. If the parameter is critical to the drilling operation this may necessitate the interruption of drilling operation to replace the damaged or malfunctioning sensor or, more likely, drilling operations will continue and the malfunctioning sensor will not be discovered until after the log data has been analyzed and it is too late to obtain correct data of the same stretch of borehole. The failure of a downhole sensor, particularly in a measuring-while-drilling environment, may not only be expensive due to the loss of critical data but may result in increased risk to both life and property due to the failure to provide crucial notice of emergency conditions which the drilling operator is expecting and relying upon during the conduction of the drilling operation.

For this reason, it would be extremely helpful to provide redundant drilling parameter sensors downhole. Thus, in the event of a failure of a single sensor or in the event of a malfunction of that sensor and the production of erroneous data, a backup is provided which substantially enhances the reliability of the overall quantity of data obtained during the logging operation.

The provision of redundant sensors for measuring borehole parameters while providing increased security with respect to data reliability, also produces the need for both increased storage and/or recording capacity downhole or increases the need to telemeter a greater quantity of data to the wellhead for surface processing. Producing additional storage, recording, and/or telemetry capacity may be extremely expensive and difficult to implement due to the environment where the equipment must be located. Thus, it is desirable to provide downhole signal processesing means whereby information obtained from redundant sensors of a single parameter may be processed and, in the event that both sensors are operating properly, the two outputs combined into a single unit of data. Further, signal processing capacity is desired to detect when one of the redundant sensors has failed to function entirely, or is producing erroneous data so that data from the properly functioning sensor can be relied on entirely at that time and an indication produced indicating the failure or malfunction by the other sensor.

Various tests and evaluation schemes can be used in the methodology used for evaluating whether or not a sensor is producing reliable data which should be either recorded or telemetered to the surface and relied upon by the drilling operator. For example, algorithms can be constructed which utilize:

a) the known physical/statistical properties

of the measured variable;

b) the known empirically determined bounds of the measurement and its rate of change behavior; and

c) the degree of correlation of the redundant data channels measuring the same parameter.

Prior art techniques for provision of redundant instrumentation have been employed but generally in such areas computer control for rocket systems and manned spacecraft systems. Redundancy is also conventionally employed in environmental support systems upon which human life depends in extremely hostile environments. However, in such systems the concomitant need to process redundant data for conservation of data handling capacity is generally not present.

The processing of a plurality of channels of data related to borehole logging has generally been of the type where a pair of logs obtained from different boreholes in a particular area are compared and correlated with one another in order to try to draw some conclusions from the relationship between the two logs. This might be done, for example, to build a statistical model of an entire field by correlating the logs from separate wells within the same field. Such a system is taught in United States Patent No. 4,310,887. Similarly, a single set of well logging data from downhole sensors might be both stored at a downhole location and transmitted to the surface for immediate use. At a later time the stored and transmitted data are compared to evaluate the reliability of the transmission system. This provides a backup against valuable data being lost and irrecoverable if the process of transmission fails. Such a systems is shown in U.S. Patent No. 4,216,536. However, in each of these applications, there is no redundancy of individual sensors for the same parameter to provide enhanced reliability of measurements nor is there a processing of data from two sensors of the same parameter to evaluate the possibility of inaccuracies or failure in one of the two sensors and to provide an enhanced reliability of the single set of data obtained from the two sensors which is in fact recorded or transmitted to the surface.

The method and system of the present invention provides an enhanced degree of reliability in data measured in a logging while drilling operation while at the same time. minimizing the additional data storage recording and/or transmission facilities required to handle redundant data. The method and system combines equally reliable data from redundant sensors into a single channel or selects the most reliable and provides an indication of either sensor failure or unreliable data from one or the other of the sensors.

The invention relates to the provision of redundant sensors to enhance the reliability of downhole data and data processing techniques for analyzing the redundant data to minimize signal storage and data handling capacity. More particularly, one aspect of the invention is directed to a method and apparatus for the use of a multichannel sensor data processing for increasing the reliability of downhole data, particularly data obtained in a measuring while drilling mode. The system employs measuring sensor redundancy together with downhole analysis of the sensor data to detect bad data points and retain only correct data to improve the reliability of downhole information without requiring increased data storage and telemetry capacity.

In another aspect, the invention includes a method and system for providing enhanced reliability in the measurement of downhole parameters within a borehole comprising a pair of detectors for sensing each downhole parameter to be measured and generating streams of datapoints representative thereof. Each stream of datapoints is analyzed relative to expected statistical norms for the datapoints and physical parameters known to be associated with the characteristics of the detectors to determine if the datapoints are within the expected ranges and parameters. A flag is generated for datapoints found to be outside of the expected ranges and parameters. The streams of datapoints found to be within the acceptable ranges and parameters are then combined for recording with the flags for any datapoints found outside of the ranges and parameters.

In yet another aspect, the invention includes the aforesaid method and system wherein analyzing each stream of datapoints includes analyzing each stream of data from the pair of sensors to determine good datapoints and to isolate bad datapoints which are out of the range of statistical norms to be expected based upon previous measurements of the same stream of data. The bad datapoints on any individual stream are then replaced with either the good datapoint from the other stream or a prior datapoint of the same stream. In addition, the datapoints are compared for correlation and determination of a scale factor by which the two are related. The streams of data are then analyzed in light of the scale factor and a flag is generated in the event that the variation in the scale factor by which the two streams correlate is outside the norm expected. A new scale factor as to the degree of correlation between the streams of datapoints is also generated.

In yet a further aspect, the invention includes a method and system for processing a plurality of channels of measured datapoints of value signals obtained from a plurality of redundant sensors of the same wellbore parameter, comprising storing a time series of corresponding portions of each of the plurality of channels and analyzing each datapoint in time response. The analysis is a determination of whether the point value falls within a

prescribed standard range of historical values and if the deviation of the point value from the standard is within the norms of historical deviation. The analysis also includes whether the point value is within a predetermined range based upon the physical and statistical norms per the parameter being measured. Each datapoint is then compared with its time associated corresponding point in each of the other channels. A scale factor is generated in response to the comparison which relates each data point to the corresponding datapoint in each of the other channels. Each scale factor is analyzed in time response to determine whether the variation in scale factor value with time between each pair of channels falls within a preselected range. Each datapoint deemed to be bad for failure to satisfy the criteria of any analysis step is then replaced with a corresponding good datapoint from another channel after multiplication of the good point value by the scale factor which relates the two channels. A flag is then generated as an indication of each bad data point and which channel it occurred in. Each good or replaced datapoint from each channel is combined into a single stream of good data which is recorded with flag indications of bad datapoints and the channel associated therewith.

Brief Description of the Drawing

For a more complete understanding of the present invention and for further objects and advantages thereof reference may now be had to the following descriptions in conjunction with the accompanying drawing:

FIG. 1 is a diagrammatic, side-elevational view of a borehole drilling operation illustrating the measurement of borehole parameters in accordance with the system of the present invention;

FIG. 2 is a block diagram illustrating the system of the present invention;

FIG. 3 is a block diagram and flow chart illustrating the operation of the system of the present invention; and

FIG. 4 is a block diagram illustrating the broad concepts involved in the present invention.

Detailed Description

Referring first to FIG. 1, there is shown a drilling rig 11 disposed atop a borehole 12. A first embodiment of the system 10 for the processing of multichannel redundant wellbore sensor data is carried by a sub 14 comprising a portion of a drill collar 15 and positioned within the borehole 12. A drill bit 22 is disposed at the lower end of the drill string 18 and carves the borehole 12 out of the earth formations 24 while drilling mud 26 is pumped to the wellhead 28. Metal surface casing 29 is shown to be positioned in the borehole 12 at the top thereof for maintaining integrity of the borehole 12 near the surface. The annular 16 between the drill string 18 and the borehole wall 20 creates a theoretically closed return mud flow path. Mud is pumped from the wellhead 28 by a pumping system 30 through mud supply line 31 coupled to the drill string 18. Drilling mud is, in this manner, forced down the central axial passageway of the drill string 18 and egresses at the drill bit 22 for carrying cuttings comprising the drilled sections of earth, rock, and related matter upwardly from the drill bit to the surface. A conduit 32 is supplied at the wellhead for channeling the mud from the borehole 18 to a mud pit 34. Drilling mud is typically handled and treated by various apparatus (not shown) such as outgassing units and circulation tanks for maintaining selected viscosity and consistency of the mud. The sub 14 is illustrative as containing a plurality of redundant sensors and other instrumentation for measuring different downhole parameters, one pair of sensors could be produced for the measurement of each. For example, the parameters weight-on-bit, natural gamma radiation, borehole inclination, borehole azimuth, mud resistivity, temperature and pressure. The sub 14 would also contain the muitichannel data processing equipment which is a part of the present invention as well as data recording and borehole telemetry equipment.

As is shown further in FIG.2, the system of the present invention includes providing a pair of sensors such as sensor A 131 and sensor B 132 for measuring the same borehole parameter. For example, the sensors 131 and 132 could each comprise a pair of gamma ray detectors positioned within the sub 15. The pair of sensors 131 and 132 have their outputs connected respectively via a data channel A 133 and a data channel B 134 into a processing system 135 for evaluating the output of the two sensors. After processing in accordance with the system of the present invention, the data is connected through a single output channel output 136 into a single recorder 137. The data recorded in unit 137 requires essentially no more space than if a single sensor had been used, but the data incorporates a significantly higher level of reliability and accuracy in that it is derived from the output of a pair of redundant sensors 131 and 132.

In the system of the present invention, sensor redundancy is used to increase the overall reliability of an individual sensor module only if malfunction of a sensor module is detected. For example, if each sensor has a probability of successful operation equal to P where P is less than 1.0, the probability of both sensors operating satisfactorily is then P^2. Further, the probability of at least one of the sensors performing satisfactorily is $2P-P^2$. Thus we have $2P-P^2>P>P^2$. If the processing system algorithms and method can always

detect the presence of a improperly functioning sensor and can identify which sensor is improperly functioning, the system reliability is $2P-P^2$. If, however, the system can only detect a failure but not identify the particular sensor which is failing, the reliability is P. And further for no screening of bad sensors, the reliability is simply P^2. The algorithm of the system of the present invention gives a sensor module reliability value somewhere between $2P-P^2$ and P, a substantial increase over the reliability value obtained if two redundant channels were simply added downhole without screening in accordance with techniques in accordance with the present invention, i.e. P^2.

In accordance with the technique of the present invention time series data are measured through two separate channels that should, when the both the sensors are functioning properly, represent the same reproducable physical measurement. The system of the present invention processes these redundant channels of data to: (1) detect bad data points, (2) detect a bad channel or channels; and (3) record the good data in a single channel and combine channels when they are both deemed to be reliable. In order to accomplish these goals, the system requires the following: (1) the known statistical and/or physical properties of the measured variable; (2) the known bounds of the measurement and its rate of change behavior both of which must be determined empirically; and (3) the degree of correlation of the two redundant data channels since they are both measuring the same parameter.

The first requirement of evaluating and detecting bad data points is determined through use of a Kalman filter. In accordance with well know techniques, historically determined parameters are used to flag and reject bad data points. A Kalman filter is used to empirically determine the average magnitude and variance of the step discontinuities in the data and the variance of the data about its mean within each step. Thus, anomalous data points are identified using the following criteria: (a) if the difference between the value in question and the mean value on either size of that value significantly exceeds the mean step size, then the point is bad; or (b) if the difference is on the order of the mean step size or greater, but the point is isolated, i.e., the mean values on both sides are the same, then the datapoint is bad. Because information is required on succeeding as well as preceding values surrounding an individual datapoint to be evaluated, common filtering requires "looking ahead" by delaying evaluation of the data to form a pattern about the datapoint to be evaluated. The present system contemplates a memory for storing a time series of corresponding portions of data from each channel. However, in one embodiment, a one point look ahead is adequate to determine isolation when Kalman filtering is used to provide estimates of the expected variance of the difference between the measured value and a predicted value.

The second manner in which the data from a pair of redundant sensors is evaluated is in accordance with the known and statistical and physical range of parameters within which variations may occur for a given set of parameters being measured. For example, if natural gamma radiation is being sensed we know that if the number of counts of the sensor is on the order of 100 then, in accordance with the physical principles of radiation sensing the expected variaton would be 100 or 10 so that the expected count for over a one second interval should range from 90 to 110. However in the event the count suddenly fluctuates between 80 and 120, i.e. a 20% variaton, it is clear that something is wrong with the sensor because the physics of gamma radiation is such that the uncertainties of the count rate should not be as high as 20%. It would be reasoned that either the sensor is bad or something is wrong with the electronics.

Moreover, there are certain individual statistical and physical ranges and variations within which the measurement of each physical parameter varies. This information is used to provide a statistical/physical test for each of the two data channels to determine whether or not it falls within the acceptable ranges.

In addition, the multichannel data from the redundant sensors is further processed in accordance with the technique of the present invention by correlating the data obtained from each of the two redundant sensors. That is, with individual sensors there is always some variation between relative efficiency of the sensors and, hence, the output indicative of a given parameter condition may be slightly different. In the case of gamma ray detection, the sensors may change with time so that the output efficiency may vary without breaking or without giving distinctly incorrect data. For example, instead of one sensor giving an output reading of 30 all the time and the other sensor reading 35, the one that was reading 35 might change to 40 because of temperature effects. Thus, in correlation, the two sensors are related to one another by a scale factor generally on the order of one, but a factor by which takes into account the individual idiosyncrasies of each sensor and is a way in which the reading of one sensor can be related to the reading of the other sensor.

Referring now to FIG. 3, there shown a block diagram and flow chart outlining the operation of the system of the present invention. As shown there, the output of a pair of redundant sensors respectively designated channel A and channel B are each input respectively over the paths 33a and 34a into

Kalman filters 41 and 42. The outputs of the Kalman filters are connected, respectively, with the data insertion circuits 43 and 44 which enables the replacement of bad datapoints which are detected. The raw data from both channel A and channel B are also directly connected to the data insertion circuits 43 and 44 over paths 33b and 34b which bypass the Kalman filter. In the Kalman filters 41 and 42 each channel of data is evaluated in accordance with standard and accepted algorithms to determined whether or not the datapoints fall within the prescribed ranges and whether or not the deviation of any point from the standard range is within the norms of deviation based upon historical parameters. That is, in the event that a particular datapoint varies significantly from the datapoint which should be expected based upon preceding and succeeding points then conclusion is drawn that the point is bad. In that case, a "Flag (1)" is raised to identify the fact that a datapoint is found to be bad and which point on channel the event occurred. The appropriate data insertion circuitry 43 and 44 is then energized to replace the bad datapoint in the bad channel by selecting the corresponding datapoint in the other channel, modified by the appropriate correlation scale factor, and substituting that point for the bad datapoint.

If the data on such channels is good or the data at a bad point, detected by the Kalman filter, has been replaced, the data on the two channels is connected into the statistical/physical testing circuits 45 and 46. These units are preprogrammed with algorithms which include information with respect to the statistical norms for data of the type which is being monitored by the sensors under consideration and, further, include information with respect to the physical range over which which data of the type being monitored by the sensors may vary. Thus, in the event that a stream of data having had datapoints replaced, as previously described, appears to vary outside of the norms or ranges through which, from a physical or statistical limitation standpoint, the data should vary, the individual channel of data which is identified to be bad is identified a a "Flag 3" and the data is replaced by the data from the channel which is believed to be good. As the statistical/physical tests are applied to each of the two streams of data, failure to meet the requirements demanded by the test also raises the question in unit 47 and 48 as to whether or not the other channel had also failed the physical test. That is, if both of the channels are outside the bounds of statistical/physical parameters, this event is significant with respect to the data analysis and a decision of either yes or no over lines 51 and 52 is recorded on the data recording unit 60. In the event channel A fails the statistical/physical test and channel B passes the statistical/physical test a "Flag 3a" condition is noted. If the reverse situation arises and channel B fails while the data of channel A passes a "Flag 3b" condition is noted. If both channels A and B fail the statistical/physical test a "Flag 4" condition arises and it is prepared to alternately record the two channels (along with the flag condition) to assist the log analyst in diagnosing the problem.

If both of the channels pass the statistical/physical test of units 45 and 46 they are each input to a correlation unit 55 wherein each datapoint from the two channels A and B are correlated one with the other to determine if the scale factor by which the two individual units are related to one another has varied and if so, within what ranges it has varied to determine the probability that the channels are still operating properly. If the two signals correlate they are combined into one and recorded. IF the two data signals are not correlated with one another by an acceptable margin, one or the other of the channels is bad. If we cannot identify which channel is bad a "Flag 5" is raised and data alternately recorded from each channel. If they do not correlate and A is known to be bad from other tests, a "Flag 2a" condition is raised and channel B recorded. Conversely, when correlation is not present and channel B is known to be bad, a "Flag 2b" condition is raised and channel A recorded. The scale factor between the two channels of acceptable data is recursively generated and fed back to both the datapoint placement circuits 43 and 44 as well as the statistical/physical test circuits 45 and 46 within both of which the scale factors relating the signals between the two sensors are required.

Referring now to FIG. 4, the overall system is illustrated in box 61 wherein the downhole processing is identified as a Condition I in the event that both the the channels are deemed to be reliable, and their result is simply added and recorded. Under Condition II, one of the channels is bad then the good channel is scaled and recorded and a flag raised identifying the condition. Similarly, under Condition III the other channel is bad, the good channel is simply scaled, a flag identifying the bad channel is raised. Under Conditions IV and V, both of the channels are deemed to be bad, a flag is raised and channels A and B are recorded, alternately, or in the event that both of the channels are deemed to be bad but one is less out of line than the other, the better channel is recorded and a flag identifying that fact raised.

The processed redundant data is passed uphole via telemetry or recorded and subsequently processed at the surface as identified in box 62 with several conventional techniques. These techniques include those such as smoothing which reduces logs such as those which include very high resolution, and hence extensive variations in parameters, to a

smoother continuity of variations more in accordance with standard logs. For example, in case of MWD logs smoothing may be employed to make the log analyzable by conventional techniques used for analyzing less sensitive wireline logs.. Deconvolution is used to recreate sharper boundaries for logs which have been rounded out by various physical parameters effecting the data. In addition, time depth conversion is used to relate the logs obtained from the redundant sensors into a depth configuration rather than a time configuration. Finally, any additional information or processing which an operator may desire could be applied to the data which is obtained from the redundant sensors with greater reliability than that which were obtained from a single sensor.

It should also be seen that the system and method of the present invention enables the utilization of a pair of sensors for each parameter to be measured in a downhole environment by keeping the enhanced statistical reliability of redundant sensors while still not increasing the data handling capacity of the telemetry system moving the data uphole nor the requirements for enhanced storage or recording capacity in order to utilize the features of redundant sensor reliability.

CLAIMS

1. A method of providing enhanced reliability in the measurement of downhole parameters within a borehole comprising the steps of:

providing a pair of detectors for sensing each downhole parameter be to be measured and generating streams of datapoints representative thereof;

analyzing each stream of datapoints relative to expected statistical norms for said datapoints and physical parameters known to be associated with the characteristics of said detectors to determine if said datapoints are within said ranges and parameters;

generating a flag for datapoints found to be outside of said ranges and parameters; and

recording the streams of datapoints found to be within said acceptable ranges and parameters for recording with the flags for any datapoints found outside of said ranges and parameters.

2. A method as set forth in claim 1 wherein said step of analyzing each stream of datapoints includes the step of analyzing each stream of data from said pair of sensors to determine good datapoints and isolate bad datapoints which are out of the range of statistical norms to be expected based upon previous measurements of the same stream of data, and replacing said bad datapoints on any individual stream with either the good datapoint from the other stream or a prior datapoint of the same stream.

3. A method as set forth in claim 1 or 2 and further including the step of comparing the datapoints of said streams of data for correlation therebetween and determination of a scale factor by which the two are related.

4. A method as set forth in claim 3 and further including the step of analyzing said streams of data in light of said scale factor and generating a flag in the event that the variation in the scale factor by which the two streams correlate is outside the norm expected, and the step of generating a new scale factor as to the degree of correlation between said streams of datapoints.

5. A method as set forth in any preceding claim wherein alternate ones of said streams of datapoints are recorded in the event both streams are found to be unacceptable.

6. A system for providing enhanced reliability in the measurement of downhole parameters within a borehole comprising:

a pair of detectors for sensing each downhole parameter be to be measured and generating streams of datapoints representative thereof;

means for analyzing each stream of datapoints relative to expected statistical norms for said datapoints and physical parameters known to be associated with the characteristics of said detectors to determine if said datapoints are within said ranges and parameters;

means for generating a flag for datapoints found to be outside of said ranges and parameters; and

means for combining the streams of datapoints found to be within said acceptable ranges and parameters for recording with the flags for any datapoints found outside of said ranges and parameters.

7. A system as set forth in claim 6 wherein said means for analyzing each stream of datapoints includes means for analyzing each stream of data from said pair of sensors to determine good datapoints and to isolate bad datapoints which are out of the range of statistical norms to be expected based upon previous measurements of the same stream of data, and replacing said bad datapoints on any individual stream with either the good datapoint from the other stream or a prior datapoint of the same stream.

8. A system as set forth in claim 6 or 7 and further including means for comparing the datapoints of said streams of data for correlation therebetween and determination of a scale factor by which the two are related.

9. A system as set forth in claim 8 and further including means for analyzing said streams of data in light of said scale factor and generating a flag in the event that the variation in the scale factor by which the two streams correlate is outside the norm expected, and means for generating a new scale factor as to the degree of correlation between said streams of datapoints.

10. A system as set forth in any one of claims 6 to 9 wherein alternate ones of said streams of datapoints are recorded in the event both streams are found to be unacceptable.

11. A method for providing enhanced reliability in the measurement of borehole parameters, comprising;

providing a pair of redundant sensors for producing a pair of data point streams each point being indicative of the value of the same borehole parameters as a function of time;

analyzing each stream of data points over a selected time period to determine whether each point falls within a prescribed range of historical values and whether the deviation of any point falls within a prescribed range of historical deviation;

generating in response to said point analyzing step an indication when a data point in either stream is found to be bad because it falls outside said range of historical values and said range of historical deviations and an indication of which stream the said point occurred;

replacing all bad data points in response to said first analyzing step with the time correspondant data point from the other stream after multiplication of the data point value by an associated scale factor or with the last prior data point in the same stream as the bad data points if the corresponding data point in both streams are bad;

analyzing each stream of data points to determine whether each data point falls within a preprogrammed range of values based upon the physical and statistical norms for the parameter being measured by the pair of sensors;

generating an indication in response to said second analyzing step when a data point in either stream is found to be bad because it falls outside the range of physical and statietical norms;

means for replacing all bad data in response to said second analyzing step with the time correspondent data point from the other stream after multiplication of that data point value by an associated scale factor;

comparing correspondent data points in the two streams to determine the degree of correlation between each respective point;

generating an associated scale factor for each data point indicative of the degree of correspondence between values produced by said sensors;

comparing the generated scale factor with a prescribed range of values to determine whether the scale factor has varied outside that range;

generating in response to said second comparing step as indication that a data point in either stream is found to be bad because its correlation scale factor falls outside the prescribed range;

replacing all bad data points in response to said second comparing step with the time correspondent from the other stream after multiplication of the data point value by an associated scale factor;

combining all corresponding good or replaced data points in the two streams into a single stream;

recording the single combined stream and all indications of bad data points when at least one stream is good; and

alternately recording each stream of data when all points in both streams are bad.

12. The method of providing enhanced reliability in the measurement of borehole parameters as set forth in claim 11, wherein Kalman filtering is employed to analyze each stream of data with respect to historical values.

13. A system for providing enhanced reliability in the measurement of borehole parameters, comprising;

a pair of redundant sensors for producing a pair of data point streams each point being indicative of the value of the same borehole parameters as a function of time;

first means for analyzing each stream of data points over a selected time period to determine whether each point falls within a prescribed range of historical values and whether the deviation of any point falls within a prescribed range of historical deviation;

means responsive to said first analyzing means for generating an indication when a data point in either stream is found to be bad because it falls outside said range of historical values and said range of historical deviations and an indication of in which stream the bad point occurred;

means responsive to said first analyzing means for replacing all bad data points with the time correspondent data point from the other stream after multiplication of the data point value by an associated scale factor or with the last data point prior in the same stream of the bad data points if the corresponding data point in both streams are bad;

second means for analyzing each stream of data points to determine whether each data point falls within a preprogrammed range of values based upon the physical and statistical norms for the parameter being measured by the pair of sensors;

means responsive to said second analyzing means for generating an indication when a data point in either stream is found to be bad because it falls outside the range of physical and statistical norms;

means responsive to said second analyzing means for replacing all bad data points with the time correspondent data point from the other stream after multiplication of that data point value by an associated scale factor;

first means for comparing correspondent data points in the two streams to determine the degree of correlation between each re-

spective point;

means for generating an associated scale factor for each data point indicative of the degree of correspondence between values produced by said sensors;

second means for comparing the generated scale factor with a prescribed range of values to determine whether the scale factor has varied outside that range;

means responsive to said second comparing means for generating an indication when a data point in either stream is found be be bad because its correlation scale factor has varied outside the prescribed range;

means responsive to said second comparing means for replacing all bad data points with the time correspondent data point from the other stream after multiplication of the data point value by an associated scale factor;

means for combining all corresponding good or replaced data points in the two streams into a single stream;

means for recording the single combined stream and all indications of bad data points when at least one stream is good; and

means for alternately recording each stream of data when all points in both streams are bad.

14. A method for processing a plurality of channels of measured data points of value signals obtained from a plurality of redundant sensors of the same wellbore parameter, comprising;

storing a time series of corresponding portions of each of said plurality of channels;

analyzing each data point in time sequence to determine (a) whether the point value falls within a prescribed standard range of historical values and the deviation of the point value from the standard is within the norms of historical deviation and (b) whether the point value is within a predetermined range based upon the physical and statistical norms for the parameter being measured;

comparing each data point with its time associated corresponding point in each of the other channels;

generating a scale factor in response to said comparison which relates each data point to the corresponding data point in each of the other channels;

analyzing each scale factor in time sequence to determine whether the variation in scale factor value with time between each pair of channels falls within a presslected range;

replacing each data point deemed to be bad for failure to satisfy the criteria of any analysis step with a corresponding good data point from another channel after multiplication of the good data point value by the scale factor which relates the two channels;

generating a flag indication of each bad data point and in which channel it occurred;

combining each good or replaced data point from each channel into a single stream of good data; and

recording said single stream of good data and all flag indications of bad data points and the channel associated therewith.

15. A method for processing a plurality of channels of measured data points of value signals obtained from a plurality of redundant sensors of the same wellbore parameters as set forth in claim 14 wherein:

said step of determining whether each data point in time sequence falls within a preselected standard range of historical values and the deviation of the point values from the standard is within the norms of standard deviation is performed by Kalman filtering of each channel of data.

16. A method for processing a plurality of channels of measured data points of value signals obtained from a plurality of redundant sensors of the same wellbore parameters as set forth in claim 14 or 15 wherein there are two channels of redundant data.

17. A system for processing a plurality of channels of signals of measured datapoints of value signals obtained from a plurality of redundant sensors of the same wellbore parameters, comprising:

means for storing a time series of corresponding portions of each of said plurality of channels;

means for analyzing each datapoint in time sequence to determine (a) whether the point value falls within a preselected standard range of historical values and the deviation of the point value from the standard within the norms of historical deviation and (b) whether the point value is within a predetermined range based upon the physical and statistical norms for the parameter being measured;

means for comparing each datapoint with its time associated corresponding point in each of the other channels;

means for generating a scale factor in response to said comparison which relates each datapoint to the corresponding datapoint in each of the other channels;

means for analyzing each scale factor in time sequence to determine whether the variation in scale factor value with time between each pair of channels falls within a preselected range;

means for replacing each datapoint deemed to be bad for failure to satisfy the criteria of any analysis step with a corresponding good datapoint from another channel after multiplication of the good point value by the scale factor which relates the two channels;

means for generating a flag indication of each bad datapoint and in which channel it occurred;

means for combining each good or replaced datapoint from each channel into a single stream of good data; and

means for recording said single stream of good data and all flag indications of bad

datapoints and the channel associated therwith.

18. A system for processing a plurality of channels of measured value signals from a plurality of redundant sensors of the same wellbore parameter as set forth in claim 17 wherein:

said means for determining whether each data point in time response falls within a preselected standard range of historical values and the deviation of the point values from the standard is within the norms of standard deviation includes Kalman filtering means for each channel of data.

19. A system for processing a plurality of channels of measured value signals from a plurality of redundant sensors of the same wellbore parameters set forth in claim 17 or 18 wherein there are two channels of redundant data.

20. A method of providing enhanced reliability in the measurement of downhole parameters within a borehole, the method being substantially as hereinbefore described with reference to the accompany drawings.

21. A system for providing enhanced reliability in the measurement of downhole parameters within a borehole, the system being substantially as hereinbefore described with reference to the accompanying drawings.

22. A method for processing a plurality of channels of measured data points of value signals obtained from a plurality of redundant sensors of the same wellbore parameter, the method being substantially as hereinbefore described with reference to the accompanying drawings.

23. A system for processing a plurality of channels of measured data points of value signals obtained from a plurality of redundant sensors of the same wellbore parameter, the system being substantially as hereinbefore described with reference to the accompanying drawings.

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